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APOLLO COMMAND MODULE PILOT AND DROGUE PARACHUTE PYROTECHNIC MORTAR TEST

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INTRODUCTION

The purpose of this test program was to functionally evaluate Apollo Command Module pilot and drogue mortars under normal and off-limit environmental conditions. The environmental conditions were: vibration, thermal-vacuum, high, low, and ambient temperatures.

The Apollo Command Module pilot and drogue mortar test was conducted by personnel within the Pyrotechnics Test Section, Thermochemical Test Branch, Propulsion and Power Division during the period from June 1 to August 15, 1967.

TEST ARTICLE DESCRIPTION

The test article consisted of pilot and drogue parachute mortars. Figure 1 shows a pilot mortar and test assembly. The drogue mortars are similar in structure to the pilot mortars, though larger. Mortar assemblies are designed to contain and eject, on command, the pilot and drogue parachutes for the Apollo Command Module.

Both pilot and drogue mortars contain redundant gas pressure cartridges. Gas pressure generated within the mortar activates a sabot (piston) which forces the parachute pack to (1) shear the pins that hold the mortar covers in place, (2) eject the parachute pack, and (3) strip the parachute from the parachute bag.

For this test program, three pilot and three drogue mortar assemblies, including the parachutes, were received from North American Aviation (NAA). Pilot chute systems were NAA Part Number ME 901-0001-0003. Pressure cartridges for the pilot mortars were Type II, NAA Part Number ME 453-0005-0002. Drogue chute systems were NAA Part Number ME 901-0001-0002; and the drogue chute pressure cartridges were Type I, NAA Part Number ME 901-0005-0001.

TEST PROGRAM AND PROCEDURE

The test program was designed to determine the ability of the pilot and drogue parachute mortar systems to function normally after being subjected to off-limit environmental conditions. Normal functioning is defined as:

a. Deployment of the parachute pack and complete strip-off of the deployment bag from the parachute canopy when the mortar is fired vertically.

b. The reaction force between the mortar and the firing fixture shall not exceed 9 000 pounds for the pilot mortar and 10 000 pounds for the drogue mortar.

The three pilot and the three drogue mortars were subjected to the same test conditions. Table I is the test matrix for evaluation of both types of mortars. Both new and rebuilt hardware were tested. Samples 1 through 3 were new hardware; samples 4 through 9 represent rebuilt hardware. Each mortar sample was rebuilt twice.

Nine different tests were performed. All mortars were acceptance tested. Only the three new mortars were subjected to vibration tests (test 2). The thermal-vacuum test (test 3) was conducted only on sample 1.

The remaining six tests were high, low, and ambient temperature firings made with dual cartridges and repeated with single cartridges. Dual cartridge testing utilized two live cartridges whereas in the single cartridge tests live and inert cartridges were used. Although single cartridge firing was not a realistic condition, the tests were conducted to determine the performance characteristics of the mortars under severe cartridge malfunction conditions.

Each mortar sample, new or rebuilt, was subjected to one temperature-environment firing. The parachute bags in the new hardware were tied to prevent chute deployment. Thus, they could be rebuilt for additional testing after new orifices were placed in the mortars. The parachute bags were not tied in the last three firings using rebuilt hardware.

Functional tests were conducted on a thrust stand. Tube and breech pressures were measured using two pressure transducers as shown in figure 1. Pressure cartridges were fired using a 5 ampere, 20 millisecond electrical pulse. A tension-compression load cell was used to measure reaction load. Parachute velocity was measured using an intervalometer consisting of four linearly arranged electrical breakwires, as shown in figure 2.

The objectives and procedures of the specific tests were as follows:

a. Test 1 was an acceptance test to determine if the mortar test samples met the manufacturer's specifications. Both bridgewire and insulation resistances were recorded for each pressure cartridge. Serial numbers and lot numbers for the pressure cartridges and initiators were also recorded.

b. Test 2 was a vibration test to observe visually any damage that might occur to the mortars as a result of the off-limit vibration tests. The mortars (samples 1, 2, and 3) were subjected to the random vibration levels shown in figure 3. They were vibrated in each of three mutually perpendicular axes for 15 minutes per axis. Figures 4 and 5 show the mortar axis orientations; figure 6 shows the pilot mortar mounted on the shaker head during the vibration test.

c. Test 3 was a thermal-vacuum test to determine if any resulting damage from high and low temperatures and rapid pressure changes had occurred. Mortar sample 1 was installed in a thermal chamber and soaked for 15 minutes at 250° ± 5° F. The sample was then removed and installed in a vacuum chamber which was rapidly depressurized. The vacuum chamber was held at less than 500 microns for a period of 30 minutes and was then rapidly brought to atmospheric pressure. This procedure was repeated using a soak temperature of -100° ± 5° F.

d. Tests 4 and 7 were high temperature firing tests to determine whether the mortar samples functioned normally after being subjected to elevated temperature. Test 4, conducted on samples 2 and 4, used dual cartridges. Test 7, using a single cartridge, was conducted on sample 7. Each mortar sample, with one or two pressure cartridges as specified, was installed in a thermal chamber. Chamber temperature was raised to 250° ± 5° F. The sample was stabilized at this temperature for 15 minutes. The sample was then removed, placed in a firing fixture, and fired within 5 minutes.

e. Tests 5 and 8 were low temperature firings. Test 5, using dual cartridges, was conducted on samples 3 and 5. Test 8, using a single cartridge, was conducted on sample 8. The basic objectives and procedures described for the previous firing test was followed, except that the chamber temperature was -100° ± 5° F.

f. Tests 6 and 9 were ambient temperature firings. Test 6, using dual cartridges, was conducted on samples 1 and 6. Test 9, using a single cartridge, was conducted on sample 9. The objectives and procedures were the same as the previous firing tests, except that the firing was conducted at ambient temperature.

RESULTS AND DISCUSSION

All the drogue and pilot parachute mortars were acceptance tested and found to be within the manufacturer's specifications during test 1. The acceptance test results for the pilot mortars are shown in table II; the results for the drogue mortars are recorded in table III.

Following test 2, the vibration test, mortar samples 1, 2, and 3 were inspected and no apparent damage was visually observed.

At the completion of the thermal-vacuum cycle (test 3), outlined in the test procedure, sample 1 was inspected. No visible damage was observed.

Samples 2 and 4 were fired with dual cartridges +250° F (test 4). Both mortars performed satisfactorily. The reaction loads were within the specified limits. The chutes were not allowed to strip from the bags, being restrained by ties. The results of test firing the pilot mortars are shown in table IV and the drogue mortar firing results are shown in table V. Figure 7 shows a drogue parachute fully deployed. Mortar samples 3 and 5 fired satisfactorily at -100° F (test 5). The reaction loads were normal. Samples 3 was restrained from chute-stripping by ties. The chute bag on sample 5 was untied and strip-off occurred satisfactorily.

Ambient temperature firing of mortar samples 1 and 6 was satisfactory (test 6). The chute bag on the drogue mortar was untied and the chute was successfully stripped from the bag.

Data from the above tests are shown in tables IV and V.

In the single cartridge, high temperature firing test conducted on sample 7 (test 7), the single cartridge separated the chute bag from the mortar tube. However, the force was not sufficient to strip the chute from the bag.

Mortar sample 8, used in the single cartridge, low temperature firing test (test 8), was cooled to -100° F and fired. The drogue mortar chute bag did not separate from the tube. The bag rose approximately half-way and then dropped back into the tube.

Mortar sample 9, fired at ambient temperature by a single cartridge, successfully separated the chute bag from the mortar tube. However the force was not sufficient to strip the chute from the bag.

CONCLUSIONS

The Apollo Command Module pilot and drogue parachute pyrotechnic mortar functioned normally after being subjected to the described off-limit environmental conditions.

The reaction force between the mortar and firing fixture did not exceed 9 000 pounds for the pilot mortar and 10 000 pounds for the drogue mortar under off-limit environmental conditions.

Three tests demonstrated the ability of the system to deploy the parachute pack and complete strip-off of the deployment bag from the parachute canopy when the mortar is fired vertically upward.

For the single cartridge firing the force was not sufficient to strip the parachute from the parachute bag. There was sufficient force to separate the parachute pack from the mortar tube for all firings except for the low temperature firing of the drogue mortar. The parachute pack, for this low temperature firing, came half-way out of the mortar tube and then dropped back.

FIGURES

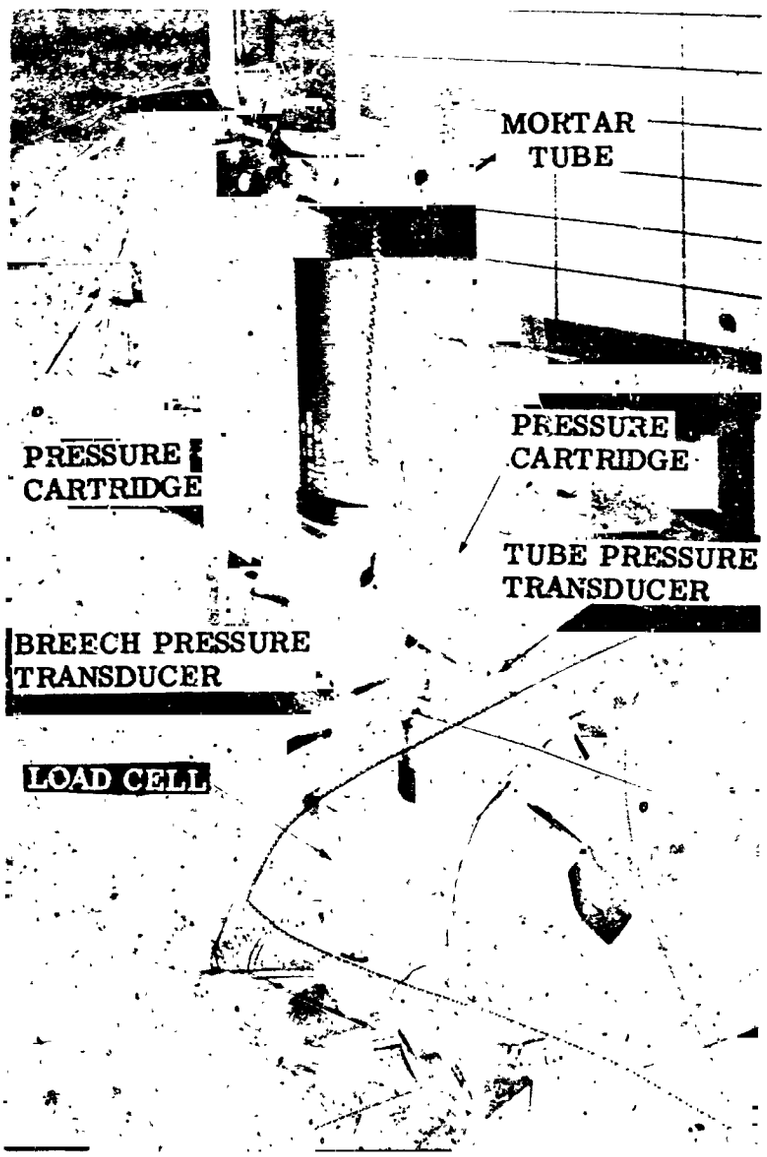


Figure 1.- Pilot mortar test assembly.

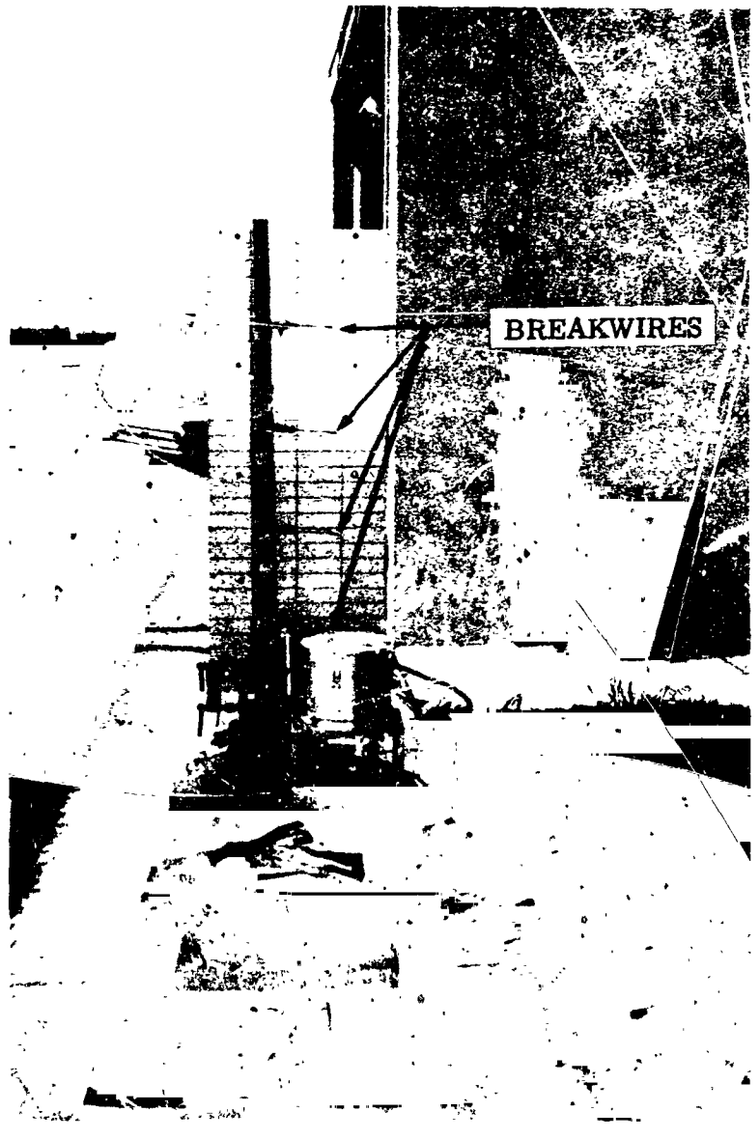


Figure 2.- Drogue mortar test assembly.

Figure 2.- Drogue mortar test assembly.

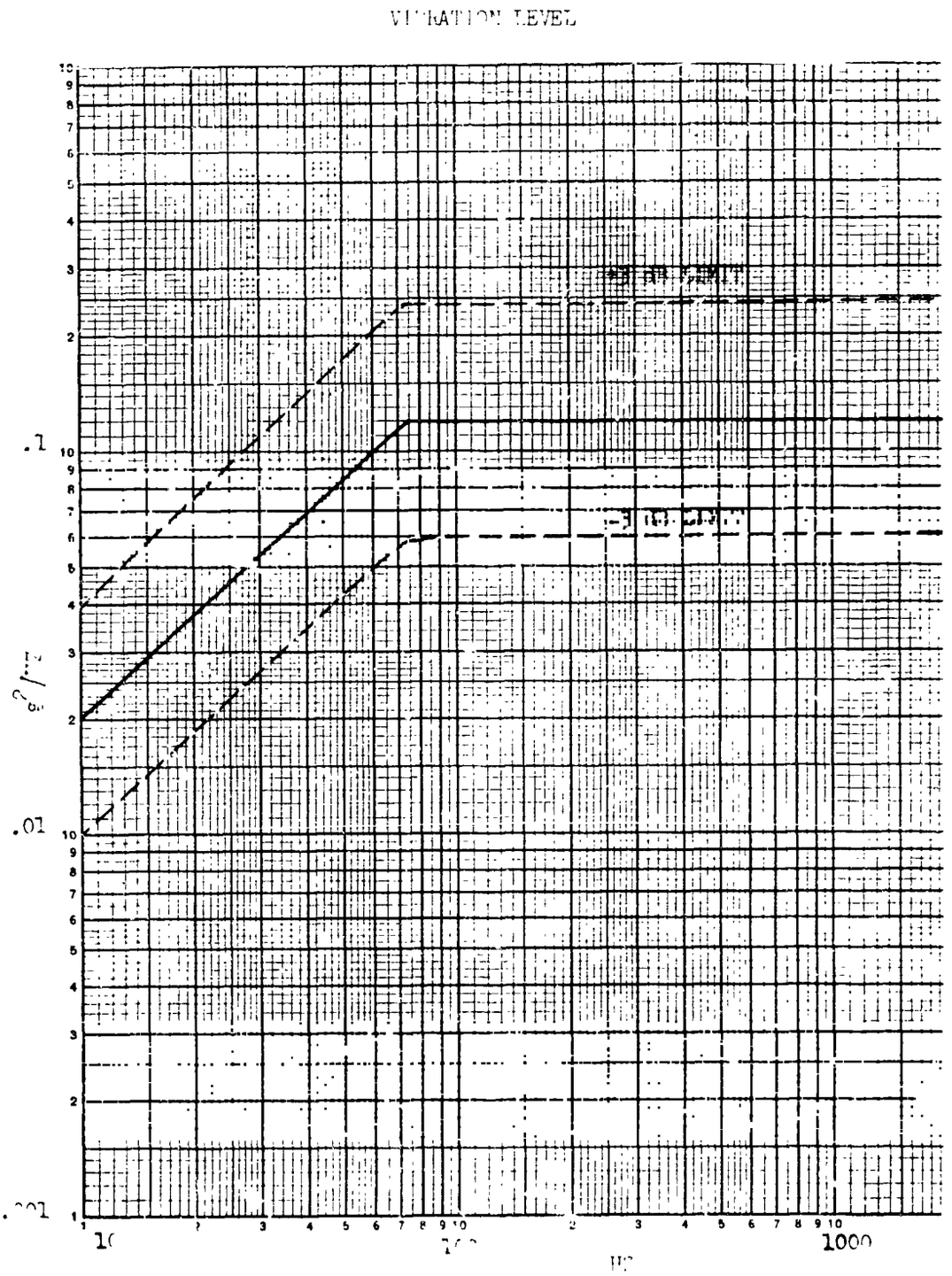
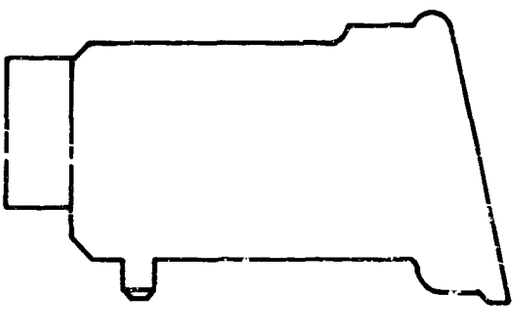
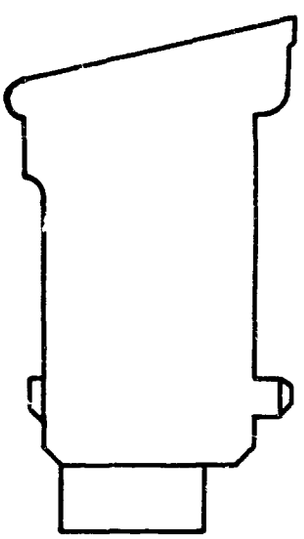


Figure 3.- Random vibration levels.

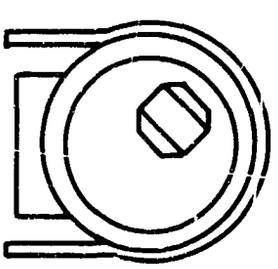


"X" AXIS



DIRECTION OF VIBRATION

"Y" AXIS



"Z" AXIS

Figure 4.- Axis orientation.

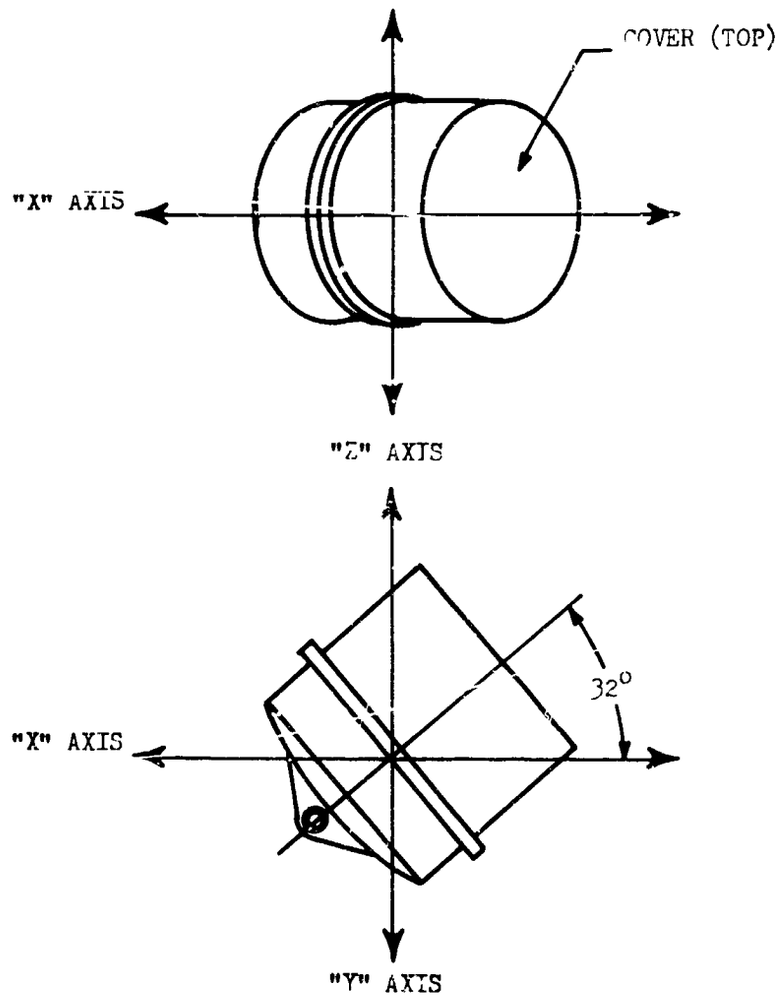


Figure 5.- Axis orientation.

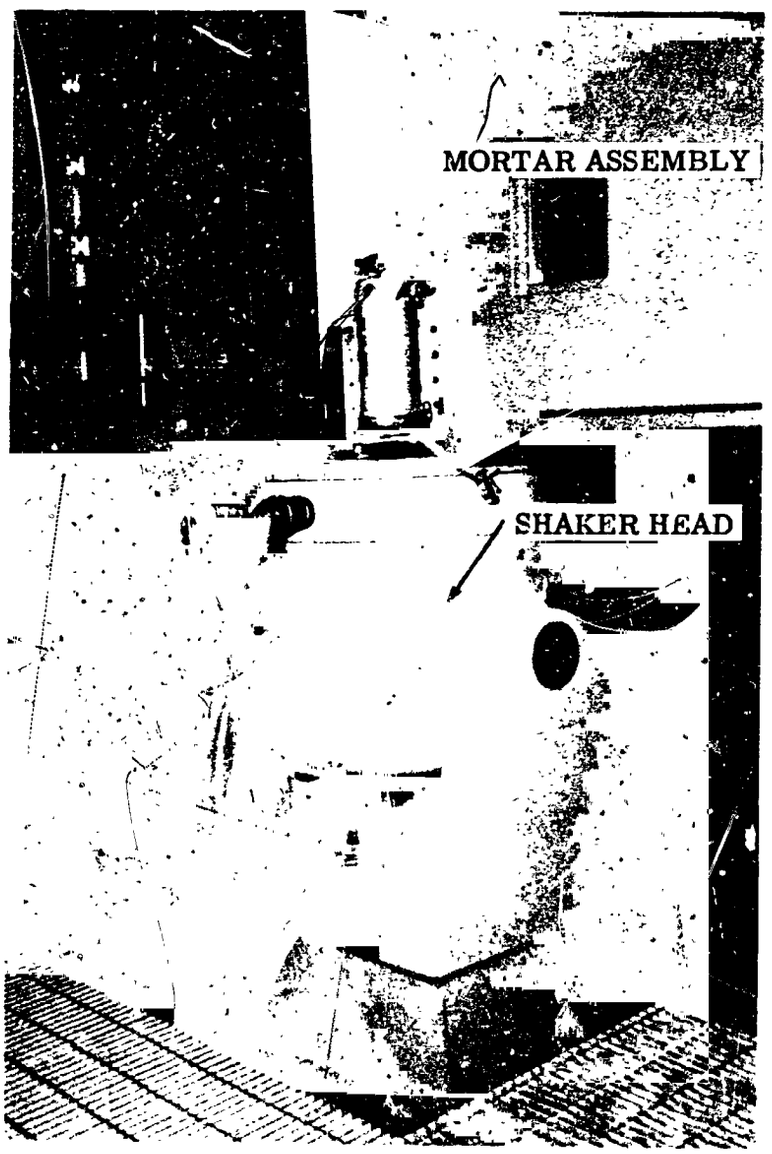


Figure 6.- Vibration test of the pilot mortar.

Figure 7.- Drogue parachute fully deployed.

TABLES

TABLE I.- TEST SCHEDULE

Test No.	Test	Test sequences[a] for Test sample[b] No.								
		1	2	3	4	5	6	7	8	9
1	Acceptance	1	1	1	1	1	1	1	1	1
2	Vibration	2	2	2						
3	Thermal-Vacuum	3								
4	High Temperature Firing (Dual Cartridge)		3		2					
5	Low Temperature Firing (Dual Cartridge)			3		2				
6	Ambient Temperature Firing (Dual Cartridge)	4					2			
7	High Temperature Firing (Single Cartridge)							2		
8	Low Temperature Firing (Single Cartridge)								2	
9	Ambient Temperature Firing (Single Cartridge)									2

[a]Test Sequence Numbers are in the order which tests are performed.

[b]Test Samples No. 4, 5, 6, 7, 8, and 9 are rebuilt mortars.

TABLE II.- ACCEPTANCE TEST DATA FOR PILOT PARACHUTE MORTARS

Sample NO.	Initiator serial No.	Initiator lot No.	Pressure cartridge serial No.	Pressure cartridge lot No.	A - B Bridgewire resistance ohms	C - D Bridgewire resistance ohms	Insulation resistance K megohms
1	0202	AMD	002	BLL	1.025	1.038	3
	0207	AMD	009	BLL	1.048	1.074	2
2	0228	AMD	016	BLL	1.023	1.072	300
	0174	AMD	017	BLL	1.040	1.066	500
3	0179	AMD	019	BLL	1.003	0.995	500
	0269	AMD	020	BLL	1.030	1.033	10
4	0258	AMD	026	BLL	1.036	1.078	250
	0334	AMD	027	BLL	1.058	1.068	350
5	0183	AMD	031	BLL	1.020	1.083	40
	0229	AMD	032	BLL	1.036	1.018	150
6	0245	AMD	022	BLL	1.017	1.054	300
	0280	AMD	023	BLL	1.080	1.129	450
7	0197	AMD	029	BLL	1.030	1.116	400
8	0175	AMD	033	BLL	1.007	0.989	700
9	0201	AMD	025	BLL	1.049	1.085	200

TABLE III.- ACCEPTANCE TEST DATA FOR DROGUE PARACHUTE MORTAR

Sample No.	Initiator serial No.	Initiator lot No.	Pressure cartridge serial No.	Pressure cartridge serial No.	A - B Bridgewire resistance ohms	C - D Bridgewire resistance ohms	Insulation resistance K megohms
1	0303	AMD	007	BLK	1.062	1.092	15
	0317	AMD	009	BLK	1.013	1.020	110
2	0286	AMD	001	BLK	.991	1.005	500
	0239	AMD	004	BLK	1.029	1.079	180
3	0276	AMD	003	BLK	1.032	1.014	800
	0292	AMD	006	BLK	1.061	1.084	50
4	0311	AMD	012	BLK	1.025	1.010	∞
	0185	AMD	011	BLK	1.066	1.076	∞
5	0295	AMD	018	BLK	1.029	1.024	∞
	0169	AMD	020	BLK	1.032	0.972	∞
6	0314	AMD	016	BLK	1.000	1.019	∞
	0196	AMD	017	BLK	1.091	1.038	∞
7	0206	AMD	013	BLK	1.063	1.041	∞
8	0310	AMD	021	BLK	1.056	1.038	∞
9	0315	AMD	014	BLK	1.028	1.067	∞

TABLE IV.- TEST FIRING DATA FOR PILOT PARACHUTE MORTARS

Sample No.	Test No.	No. of pressure cartridges	Tube pressure psig	Breech pressure psig	Reaction load lbs	Firing temperature $^{o}_{F}$	Parachute pack velocity ft/sec
1	6	2	246	10,770	5,150	Ambient	133.3
2	4	2	230	10,700	4,680	250	125.8
3	5	2	190	12,750	6,065	-100	137.9
4	4	2	160	10,520	3,650	250	118.3
5	5	2	194	10,990	5,275	-100	112.4
6	6	2	203	11,190	4,740	Ambient	124.2
7	7	1	102	5,380	2,540	250	73.5
8	8	1	152	5,370	3,145	-100	58.8
9	9	1	169	6,240	2,895	Ambient	93.9

TABLE V.- TEST FIRING DATA FOR DROGUE PARACHUTE MORTARS

Sample No.	Test No.	No. of pressure cartridges	Tube pressure psig	Breech pressure psig	Reaction load lbs	Firing temperature °F	Parachute pack velocity Ft/sec
1	6	2	73.2	15 050	7740	Ambient	78.4
2	4	2	73.4	15 500	7630	250	63.7
3	5	2	79.2	15 500	6575	-100	81 3
4	4	2	67.8	15 420	7110	250	59.0
5	5	2	52.5	14 320	5960	-100	98.0
6	6	2	81.5	15 050	7165	Ambient	64.9
7	7	1	40.6	6 930	2720	250	36.7
8	8	1	37.3	5 770	3225	-100	----
9	9	1	47.4	6 140	4190	Ambient	33.1